Development of Fuel-Flexible Combustion Systems Utilizing Opportunity Fuels in Gas Turbines

Reduced Energy Consumption through the Development of Fuel-Flexible Gas Turbines

Gas turbines—heat engines that use high-temperature and high-pressure gas as the combustible fuel—are used extensively throughout U.S. industry to power industrial processes. The majority of turbines are operated using natural gas because of its availability, low cost, and reliability. However, a combination of recent factors, including volatility in fuel supply and pricing, global concerns about carbon emissions, and excess risk from heavy reliance on a single energy source, have made the utilization of natural gas substitutes such as industrial, municipal, and agricultural opportunity fuel sources very attractive from environmental and economic standpoints. Nevertheless, a major barrier to the utilization of opportunity fuels remains in the inability of industrial gas turbines to operate effectively when powered by such fuels.

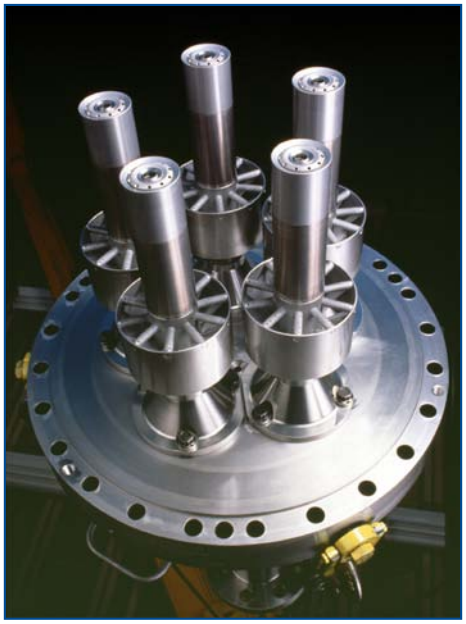

Figure 1. A Dry-Low NO_x combustor end cover and premixing fuel nozzles. Evolutionary and revolutionary concepts will be evaluated in order to increase the fuel flexibility of gas turbine combustion systems.

This project aims to address this barrier by developing and testing new fuel-flexible gas turbine nozzle technology concepts that will enable end users to efficiently generate power and heat from industrial off-gases and gasified industrial, agricultural, or municipal waste streams, as well as blends of these opportunity fuels with readily available pipeline gases. The project will develop fuel-flexible premixer technologies to maximize the interchangeability of fuels in gas turbine configurations. The team will also develop plasma-assisted fuel nozzle technology that will enable gas turbine operation using fuel streams with ultralow British thermal unit values, such as very weak natural gas, highly diluted industrial process gases, or gasified waste streams, beyond the capability range of current product offerings.

Benefits for Our Industry and Our Nation

Implementing fuel-flexible gas turbines, which provide a high-efficiency, low-emissions source of electricity and process heat, will have major energy, economic, and environmental benefits, including the following:

- Economic benefits through avoided waste disposal fees
- The release of significantly fewer air pollutants due to advanced combustion technology
- A reduction of solid hazardous waste through the use of gasifier technology
- The utilization of an untapped energy source with an available energy substitution potential of up to 4 quadrillion Btu per year from biomass, 1.35 quadrillion Btu from solid municipal waste, 525 trillion Btu per year from petroleum coke, and 46 trillion Btu per year from black liquor

Applications in Our Nation's Industry

The vast majority of industrial natural gas use comprises boilers that raise steam, heat water, and cogenerate electrical power. Thus, the potential applications of the project technology are in industries such as the food and beverage, petrochemical, pulp and paper, refining, steel and metals, and cement and glass manufacturing industries. More specifically, the project technology is expected to find an opportunity fuels market using industrial off-gases, digester gases, gasified solid waste, refinery off-gases, and steel mill gases.

Project Description

The goal of this project is to develop a low-emission, efficient, fuel-flexible combustion technology that enables operation of a given gas turbine on a range of opportunity fuels that lie outside of current natural gas–centered fuel specifications.

Barriers

- Fuel-flexible operability using dry-low NO_x emissions technology
- Application of plasma under gas turbine combustor conditions
- Fuel composition variability from gasified waste streams
- Flame stability/robust combustion on fuels with less than 125 Btu per standard cubic foot

Pathways

First, the project team will define and evaluate fuel-flexible combustor nozzle concepts for utilization with a wide range of opportunity fuels. The team will also develop and validate analytical tools that will be useful in this program and in later applications of fuel-flexible combustion concepts. Experimental evaluation of fuel-flexible nozzle concepts and the validation of model predictions will follow. Finally, the team will design, build, and test the down-selected nozzle hardware at full gas turbine combustion conditions using target opportunity fuel blends. Experimental results will be compared against model predictions, and the concepts will go through one last round of optimization and retesting.

Milestones

This project started in October 2008.

- Year 1: Definition of target demonstration gas turbine architecture, combustion conditions, opportunity fuel scope of interest, and target combustion performance values and success criteria
- Year 1: Definition of technology concepts (minimum of three advanced fuel-flexible premixers and three plasma-enhanced fuel nozzles)
- Years 1–2: Evaluation and down-selection of new, well-defined nozzle concepts with reasonable promise of success
- Years 1–2: Bench-scale experiments and evaluation of fuel nozzle concept hardware; risk retirement for all risks except those requiring high-pressure combustion testing
- Year 2: Concept reevaluation and redesign for performance improvements; definition and plan of down-selected concepts for high-pressure testing
- Year 3: Evaluation of concepts at full combustor conditions, including completion of high-pressure testing, data evaluation, and report completion

Commercialization

Technology commercialization will focus on opportunity fuels that may not currently be served well by high-efficiency gas turbines and on those that would benefit from fuel-flexible low-emissions combustion technology advancement. The final commercial goal of this program is a validated fuel nozzle technology and design tools for a fuel-flexible, retrofittable, combustion system for a GE gas turbine. GE is likely to partner with an industrial architect and engineering firm to design plant upgrades and an established gasifier vendor (including GE) for solid-phase opportunity fuels.

Project Partners

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A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

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